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Experience of verification and calibration mathematical model of flood routing by the reservoir

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Abstract

The research is dedicated to adapting of one-dimensional mathematical model of flood routing through reservoir with tributary. The program complex Mike 11 was used. The object of the study was the Cheboksary reservoir on the river Volga of Russia. Source data for development model were the digital elevation model, built on the base of open source GIS and of hydro-logical database of the region. Schematization of model takes into account the characteristics of flow in difficult areas of the reservoir. Cross-sections were represented with help polygonal configuration in accordance with the method of branched channel. As a result the universal model was built for flood and low-flow conditions, allowing solve the most diverse tasks. This model allows for the calibration calculations use the graphs of water discharges and levels in dependent on time. The calibration results have showed good agreement between the calculated and measured results, allowing reliable forecasts on the base of the developed models.

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Keywords: reservoir, digital elevation model, mathematical model, calibration.

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1. Research background

Currently, the scientific and practical significance of the problem relevant integrated water resources management, which has influence on almost every sector of the state. The reservoirs on the rivers significantly alter the natural landscape and the water regime, which in turn, has alter on the life of society. Using numerical simulation programs of the insationare flow together with geographic information systems GIS allows a reliable and visually analyze of natural and anthropogenic processes.

Object of study of this work is a reservoir on the Volga River in the area between the dams Cheboksarskaya and Nizhegorodskaya, which is part of the Volga-Kama cascade - the longest European transport waterway (Figure 1).

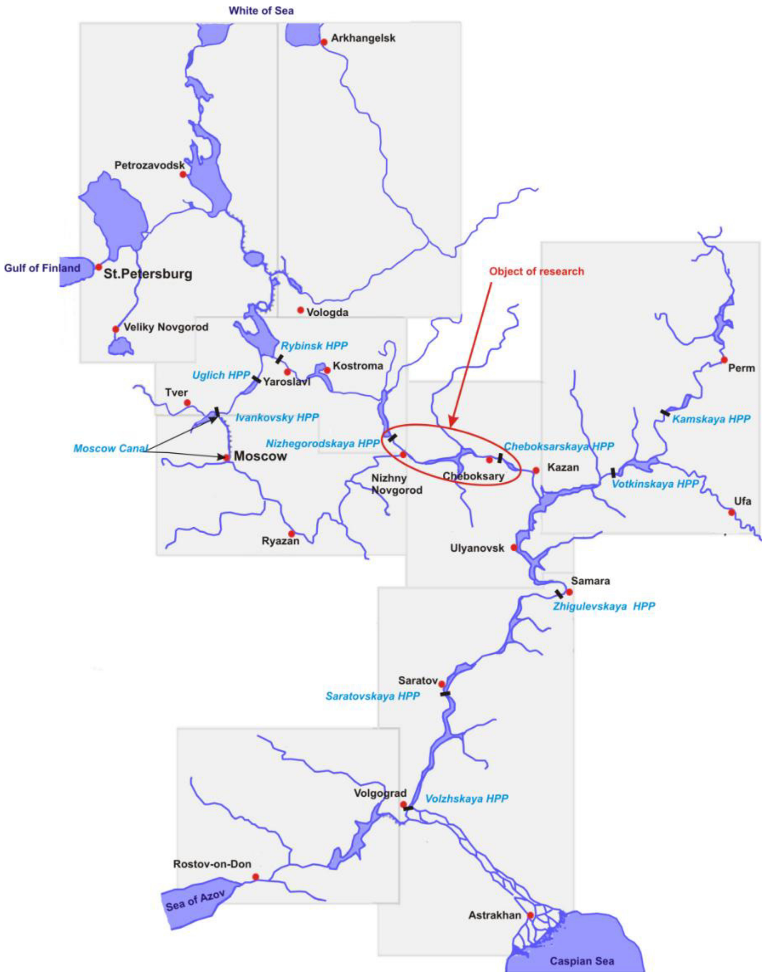


Fig. 1. Network of transport waterway in the European part of Russia

Currently supported an Cheboksarskaya dam normal headwater level (NHL) 63 meter. At the same time the construction was designed to NHL=68 meter. The ground for this is protest the regional against the flooding of agricultural lands. However, the low NHL creates impossibe conditions of navigation on the upper segment of channel, which was out of backwater, at the maximum NHL flooded large areas

The main problem is solved at this facility is to increase the water level for the improvement of navigation, taking into account the minimum area of the flooding.

2. Description of the research object

2.1. Initial data

Hydrological data. The Volga river network of the Nizhny Novgorod region, Republic of Mari El and Cheboksarskaya is very large and includes more than 9000 channel (Table 1).

Table 1. The main characteristics inflows of the reservoir [1] [2].

Name of inflow	Distance from theestuary/ Nizhegorodskaya HPP, km	Length of river,km	Catchment area, km^2
	the right inflow		
Chernaya	2276/12	41	249
Trestyanka	2274/14	17	0
Vetlyana	2267/21	5	9,1
Zhuzhla	2257/31	18	0
Pyra	2253/35	36	155
Chernaya	2239/49	19	61,2
Levinka	2238/50	1,5	106
Oka	2231/57	1500	245000
Rahma	2205/83	18	132
Kudma	2182/106	114	3220
Alferovka	2169/119	17	105
Sundvik	2137/151	97	1120
Valava	2137/151	19	112
Sura	2064/224	841	67500
MalayaYung	2023/265	24	79,5
Cheboksarka	1960/320	13	75,7
	the left inflow		
Uzola	2265,6/22	147	1920
Linda	2242/46	16	64,9
Vezloma	2228/60	52	408
Nuzhenka	2216/72	10	11,8
Vatoma	2196/92	52	355
Nyzhma	2163/125	41	233
Kerzhenets	2142/146	290	6140
Nygma	2100/188	16	103
Dorogucha	2042/246	94	670
Vetluga	2023/265	889	39400
Rutka	2016/272	153	1950
Arda	2009/279	44	351
Parat	1989/299	51	586
Kuvshinka	1950/338	10	114

For the simulation was selected 3 largest inflow: Oкa (length of 1500 km, catchment area of 245 km^2); Sura (length of 841 km, the catchment area of 67.5 km^2); Vetluga (length of 889 km, the catchment area of 39400 km^2);

Input data on hydrometric gauges Cheboksary hydroelectric reservoir and its inflow, analysis of hydrological information was based on data published on the website of Water Register and Cadastre [2] and State Water Catalog [3];

Topographic data. Digital Elevation Model (DEM) was created using the program ArcGis 9.3 and ArcView 3.2 on the basis of SRTM data and depth maps [4], [5], [6].

Data of structure.

Nizhegorodskaya HPP: includes 8 hydroelectric hydropower, spillway tile of dam, earthen dams, two navigation pass, spillway and water outlet.

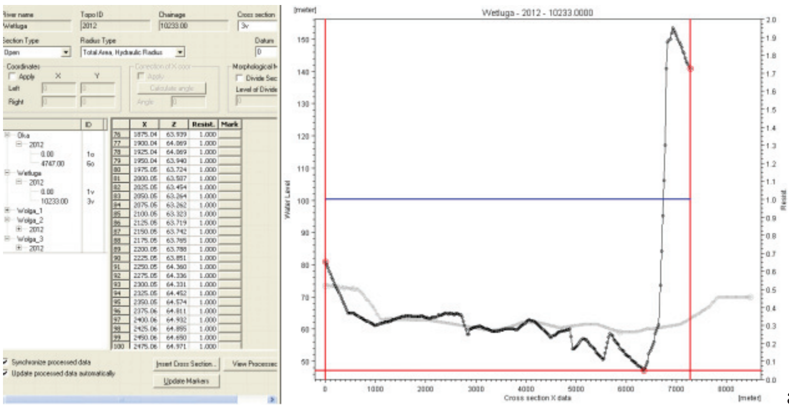
Cheboksarskaya HPP: includes a hydroelectric hydropower with 18 hydraulic units, combined with spillway, spillway tile of dam, embankment dam, navigation pass.

2.2. Create the model for simulation

Technology of production cross sections using GIS was the following: in ArcView 3.2 was loaded a digital elevation model (DEM) (Figure 2, b), using the module PE+ developed by ET Spatial Techniques [8].

Were produced sectional elevation along the line of the cross section from left bank to right, the obtained cross section was converted into text format and uploaded to the editor of the cross-section of the program Mike 11 (Figure 2, a).

The result was built 162 of the cross section.



a)

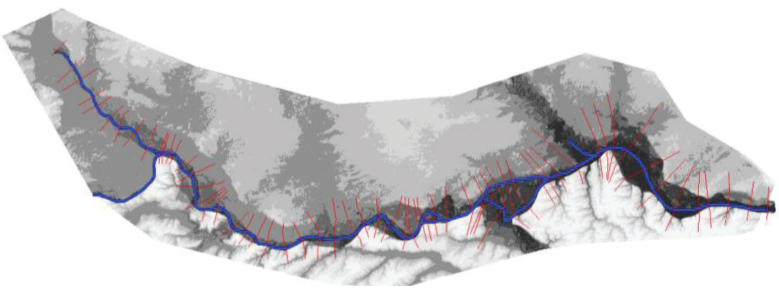


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Fig2: a) Sample database cross-sections in the program Mike 11

b) The surface constructed by interpolation GRID, schematization of reservoir

2.3. Boundary conditions and calibration of model

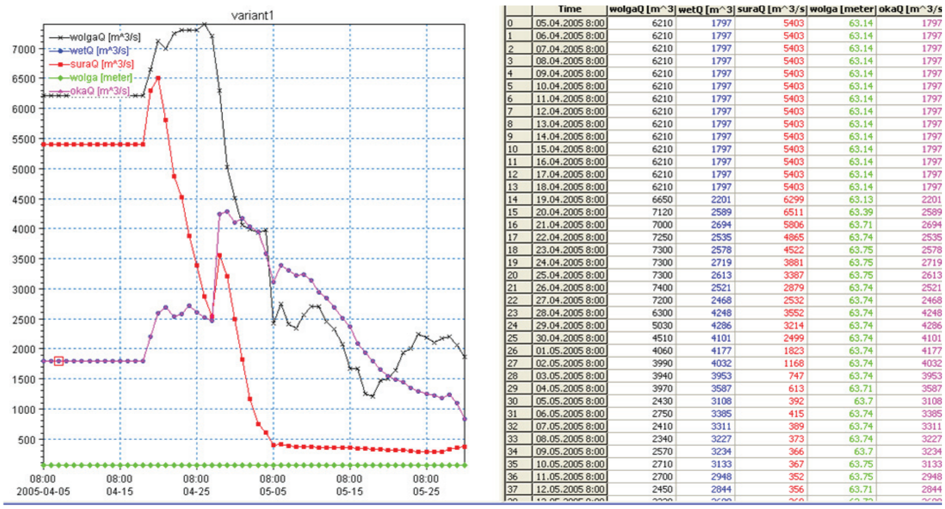
The boundary conditions of the model are shown in Table 2.

Table 2. The characteristics of the boundary conditions

Name of the boundary conditions	parameter
Nigegorodskaya HPP	Discharge, m^3/s
River Oka	Discharge, m^3/s
River Sura	Discharge, m^3/s
River Vetluga	Discharge, m^3/s
Cheboksarskaya HPP	Water level, m

The calibration of model has been carried out for unstady conditions. The flood peak has been selected at the end of April 2005. During this period, the reservoir and its inflows, there was a strong difference in the occurrence of peak values.

Therefore, the calibration was used for the period of 1.5 months from mid-April to end of May (Figure 4).



	Time	wolgaQ [m^3	wetQ [m^3	suraQ [m^3/s	wolga [meter	okaQ [m^3/s
0	05.04.2005 8:00	6210	1797	5403	63.14	1797
1	06.04.2005 8:00	6210	1797	5403	63.14	1797
2	07.04.2005 8:00	6210	1797	5403	63.14	1797
3	08.04.2005 8:00	6210	1797	5403	63.14	1797
4	09.04.2005 8:00	6210	1797	5403	63.14	1797
5	10.04.2005 8:00	6210	1797	5403	63.14	1797
6	11.04.2005 8:00	6210	1797	5403	63.14	1797
7	12.04.2005 8:00	6210	1797	5403	63.14	1797
8	13.04.2005 8:00	6210	1797	5403	63.14	1797
9	14.04.2005 8:00	6210	1797	5403	63.14	1797
10	15.04.2005 8:00	6210	1797	5403	63.14	1797
11	16.04.2005 8:00	6210	1797	5403	63.14	1797
12	17.04.2005 8:00	6210	1797	5403	63.14	1797
13	18.04.2005 8:00	6210	1797	5403	63.14	1797
14	19.04.2005 8:00	6650	2201	6299	63.13	2201
15	20.04.2005 8:00	7120	2589	6511	63.39	2589
16	21.04.2005 8:00	7000	2694	5806	63.71	2694
17	22.04.2005 8:00	7250	2535	4865	63.74	2535
18	23.04.2005 8:00	7300	2578	4522	63.75	2578
19	24.04.2005 8:00	7300	2719	3881	63.75	2719
20	25.04.2005 8:00	7300	2613	3387	63.75	2613
21	26.04.2005 8:00	7400	2521	2879	63.74	2521
22	27.04.2005 8:00	7200	2468	2532	63.74	2468
23	28.04.2005 8:00	6300	4248	3552	63.74	4248
24	29.04.2005 8:00	5030	4286	3214	63.74	4286
25	30.04.2005 8:00	4510	4101	2499	63.74	4101
26	01.05.2005 8:00	4060	4177	1823	63.74	4177
27	02.05.2005 8:00	3990	4032	1168	63.74	4032
28	03.05.2005 8:00	3940	3953	747	63.74	3953
29	04.05.2005 8:00	3970	3587	613	63.71	3587
30	05.05.2005 8:00	2430	3108	392	63.7	3108
31	06.05.2005 8:00	2750	3385	415	63.74	3385
32	07.05.2005 8:00	2410	3311	389	63.74	3311
33	08.05.2005 8:00	2340	3227	373	63.74	3227
34	09.05.2005 8:00	2570	3234	366	63.7	3234
35	10.05.2005 8:00	2710	3133	367	63.75	3133
36	11.05.2005 8:00	2700	2948	352	63.75	2948
37	12.05.2005 8:00	2450	2844	356	63.71	2844
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

Fig.4. Example boundary conditions flood in April-May 2005

As control points gauging were adopted in the settlement Balakhna, Nizhny Novgorod, Vasilsursk, Kozmodemyansk, Cheboksary. The results of the first calculations with a coefficient of roughness obtained above showed a large discrepancy in the upper section, which is associated with a narrow cross-section, the extended section of the backwater, as well as the influence on the hydrodynamics of a large inflow of Oka river .

It was decided to hold the zoning of the reservoir area on the roughness coefficient. for the reservoir area of the NP Prosek to the alignment of the Cheboksary hydroelectric value of n=0,023, upstream value n=(0,023 to 0,037). Final adoption later in the calculations presented by the zoning option (Figure 5).

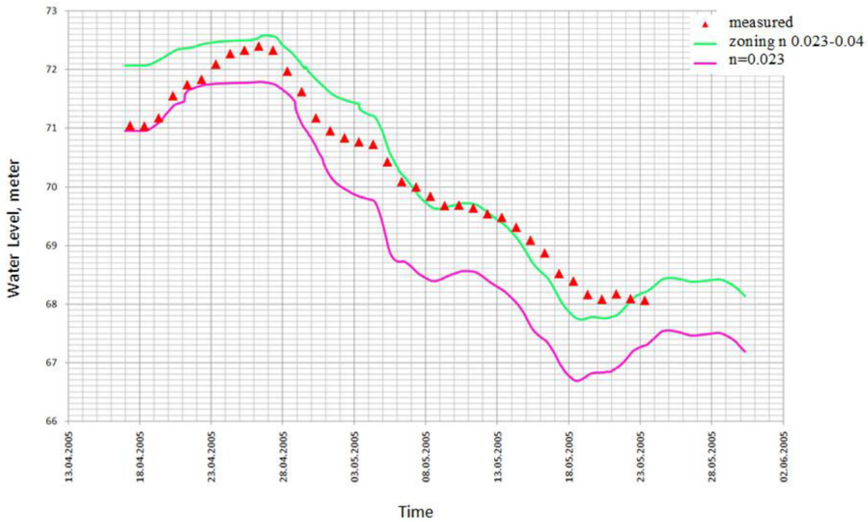


Fig. 5: Result of instationary calibration for two variants

Analysis of flood routing

Different variants were chosen for the analysis of increasing the flooded area at the level of change in various hydrological conditions low water (02. August 2011) floods peak (30. April 2010) (data in table 3), the maximum values in reference points on unsteady schedule April-May 2005.

Table 3. The quantitative characteristics of the boundary conditions

Name of the boundary conditions	parameter	02.08.2011	30.04.2010
Nigegorodskaya HPP	Discharge, m^3/s	1300	4520
River Oka	Discharge, m^3/s	640	4430
River Sura	Discharge, m^3/s	188	323
River Vetluga	Discharge, m^3/s	102	1027
Cheboksarskaya HPP	Water level, m	63.15	63.21

Calculation points with marks of water level were loaded into a GIS. Water level has been assigned to the corresponding cross-sections. Built TIN surface of the water level to be calculated for the 6 variants. TIN surfaces were converted to GRID (regular grid) by bilinear interpolation increments of 25 m. Using Spatial Analyse calculator module was carried out subtraction between the surface topography and water level for the different options. As a result, the relative surface were obtained in which the value of "-" meant below the water line. Using a built-in number of cells below the edge defined in GIS statistics tool. This value was multiplied by the area of the cell. The resulting value is the reservoir area at different variants. The conclusion was made in view of calculation of the percentage increase in the flooded area on three dates (Figure 6 a,b, 7 a,b, 8 a, b).

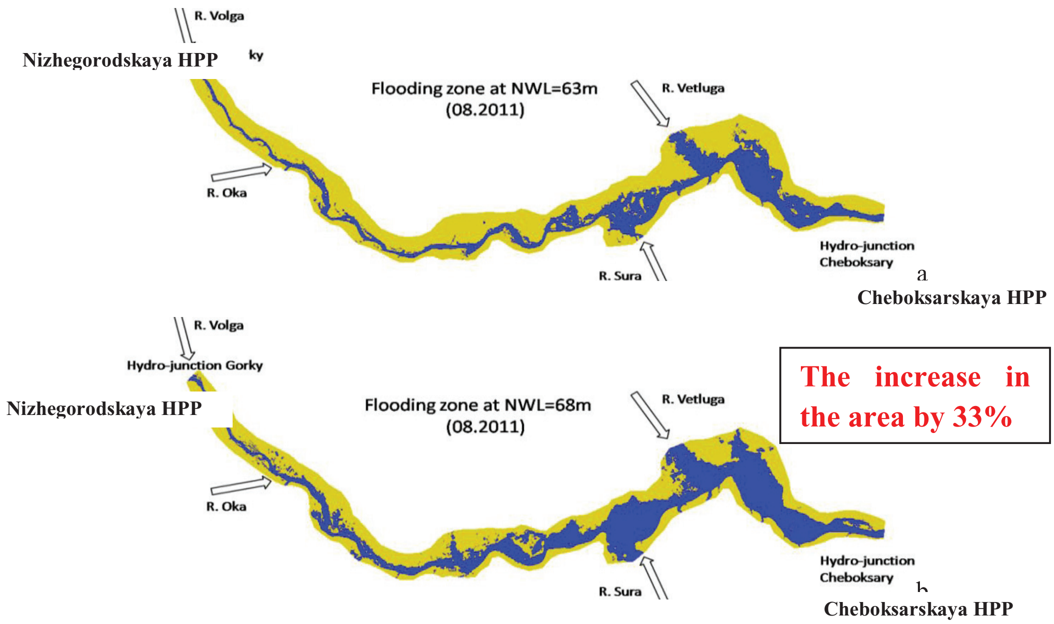


Fig. 6. The results of simulation for: low flood conditions 08.2011 enhance the NWL = a) 63 and b) 68 meter

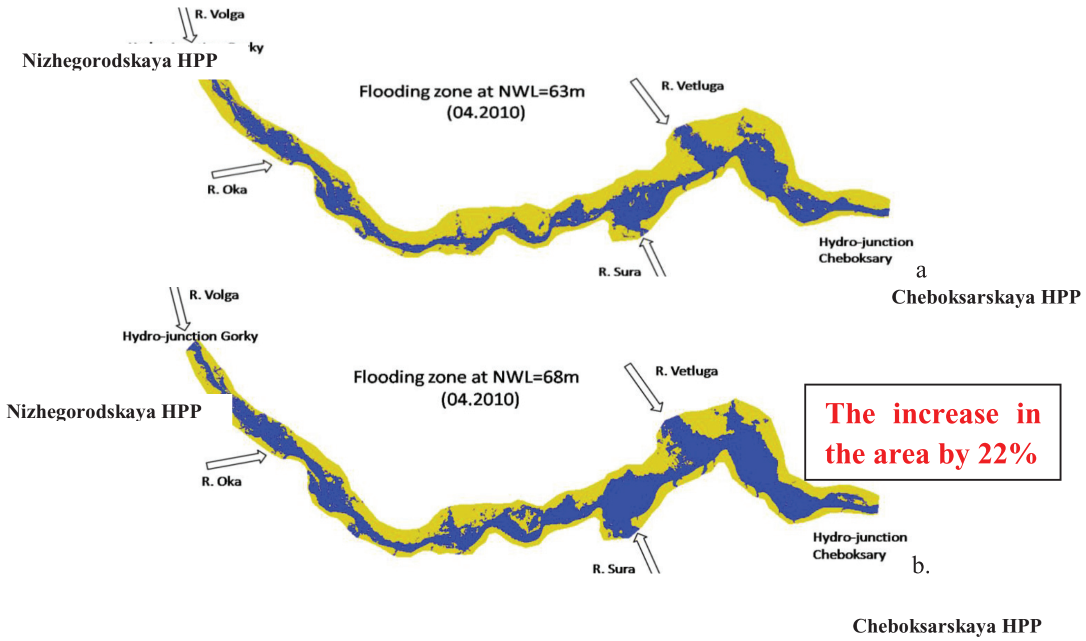


Fig. 7. The results of simulation for medium flood conditions 04.2010 enhance the NWL = a) 63 and b) 68 meter

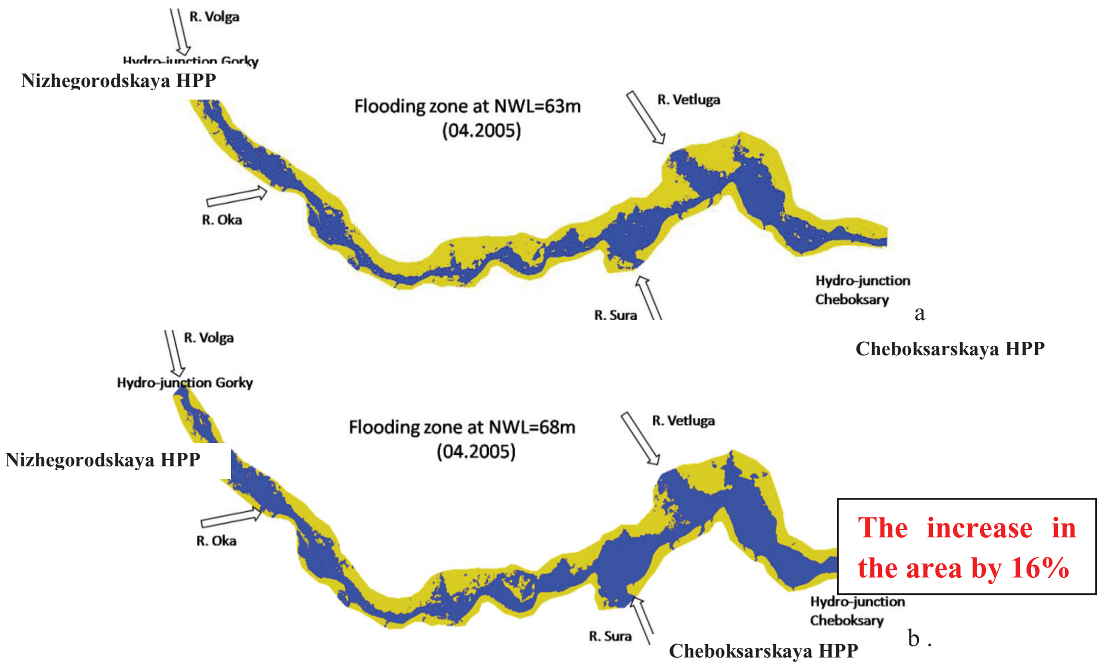


Fig. 8. The results of simulation for high flood conditions 04.2005 enhance the NWL = a) 63 and b) 68 meter

3. CONCLUSIONS

The predictive calculations were carried out , the purpose of which is the determination of the flood zone as a result of increasing water level up to 68 m. The result is the value of increasing the flooded area, in percent, in accordance with which in conditions of low water the reservoir area will increase by 33 %; In conditions of high water average of 22%; In conditions of high floods, such as in April 2005 the boundary of the high water increases by 16%.

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